

HEC I/O Measurement and Understanding

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Understanding production workloads:

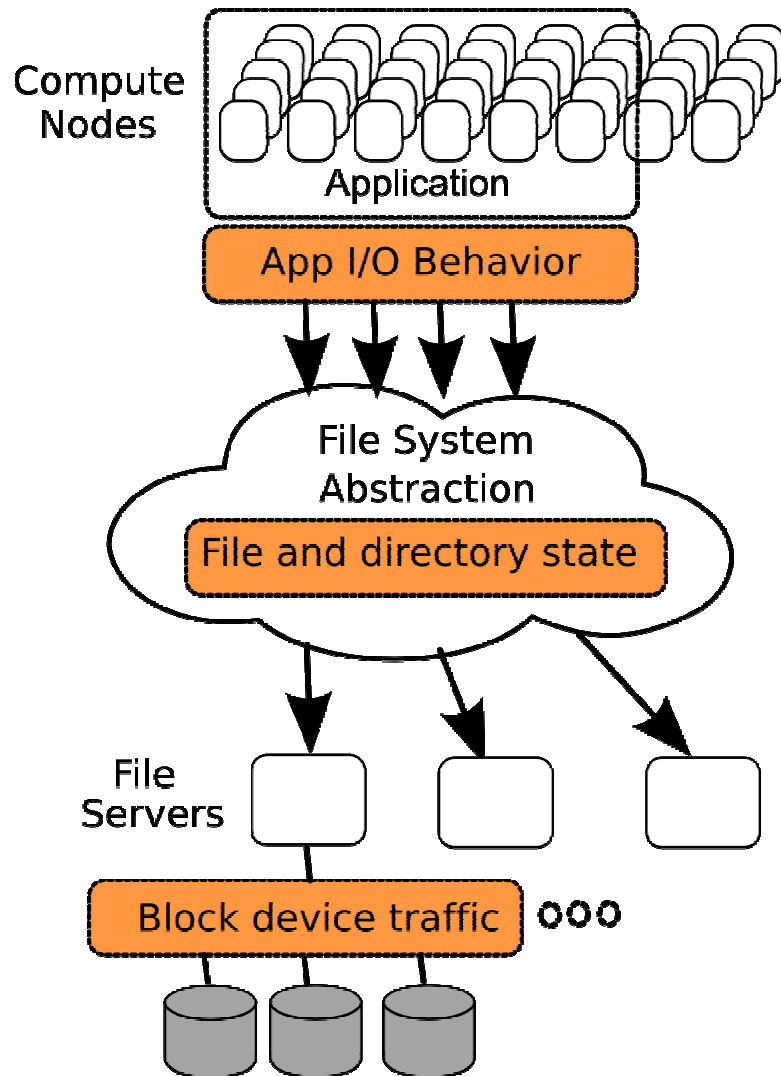
Current technology

- Key questions for scientists:
 - How can we guide application tuning to improve productivity?
- Key questions for I/O researchers:
 - What tools and resources are (or are not) being used? How do we plan for the future?
- Key questions for administrators:
 - Where should tuning and support efforts be focused?

There is no reason we shouldn't be able to answer these questions now!

- Observing production workloads is critical
- Real-world workloads often include a variety of applications not represented by popular benchmarks, especially on open science systems

Where can we collect data? Three views



- What did the application intend to do? How does it access its data?
- What are the characteristics of data at rest? How large are the files and who owns them?
- What workloads are being serviced at the hardware level?

Each view may offer a different perspective on the same overall workload.

Understanding application I/O behavior with Darshan

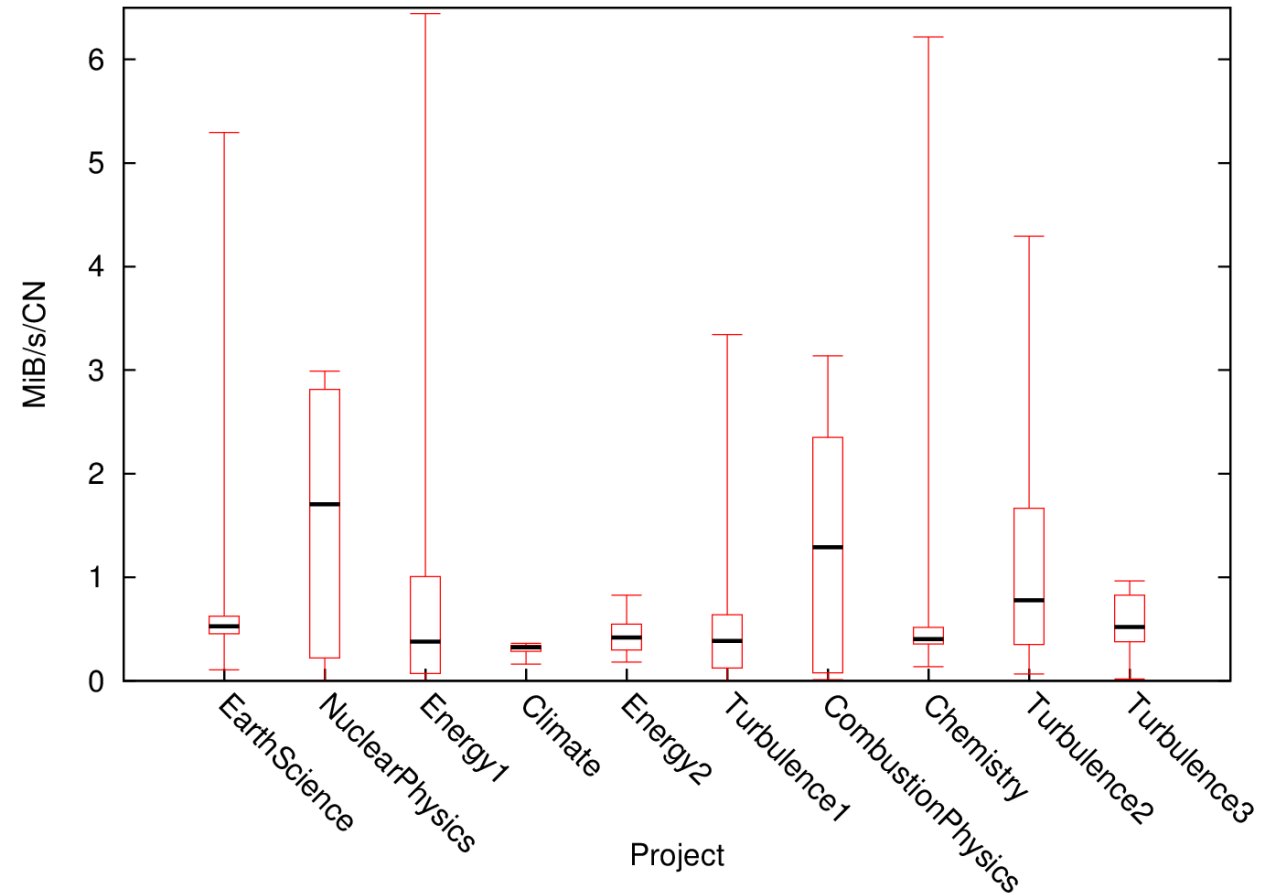
- Transparently capture as much I/O access pattern information as possible from production jobs
 - Enabled by default since January 2010 on the Intrepid BG/P system at Argonne
 - Currently instruments ~ **60% of all core hours** consumed on the system
- Darshan provides application-level characterization with file and process granularity
 - Does *not* capture full I/O traces; instead it records counters, histograms, access patterns, and strategically chosen timestamps related to I/O activity
 - Low overhead at runtime; reduction, compression, and storage is performed at MPI_Finalize() time
- Not as in depth as some tools, but its low overhead allows us to observe production activity that would otherwise go unnoticed
- Repository of anonymized logs available for public use

<http://www.mcs.anl.gov/darshan>



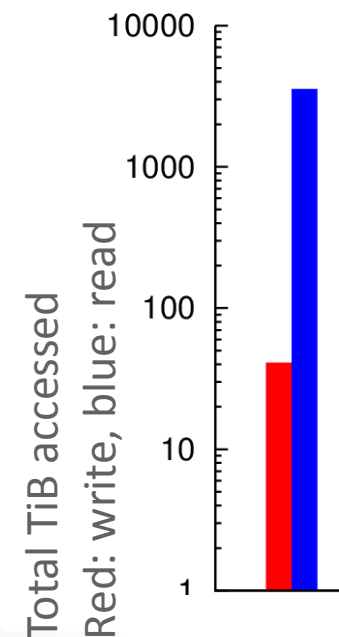
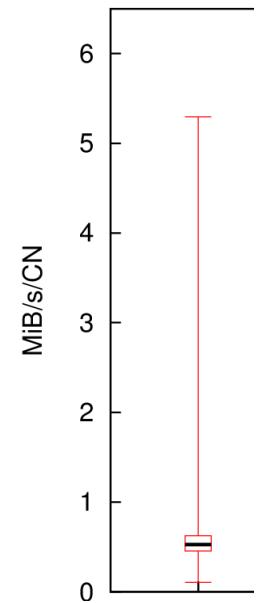
Observing behavior across application domains

- Normalized metric to compare I/O performance across jobs
- Accuracy is limited, but it provides some indication of which applications are most interesting
- Many different I/O strategies used by different applications!

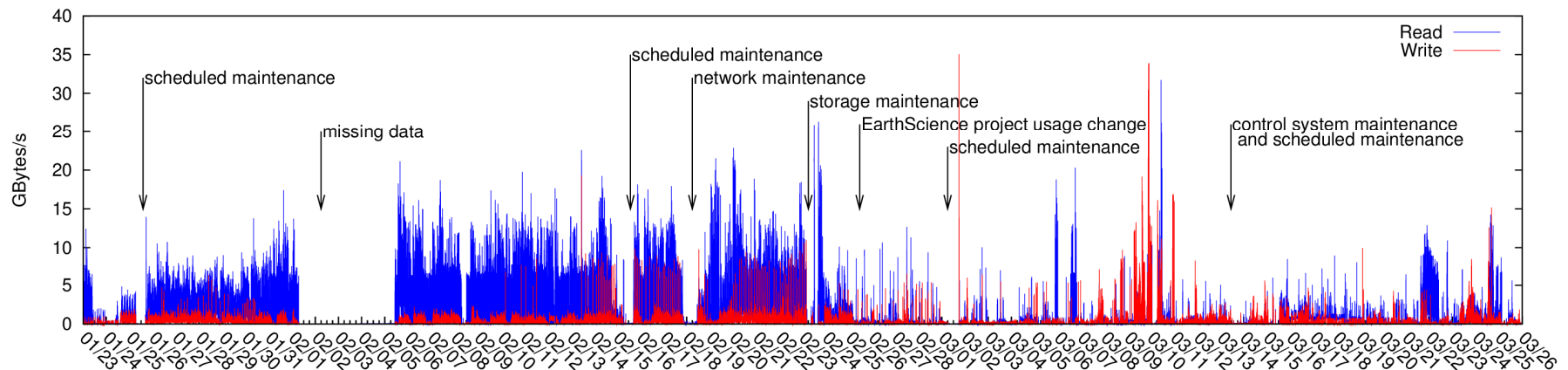


Investigating and tuning individual applications

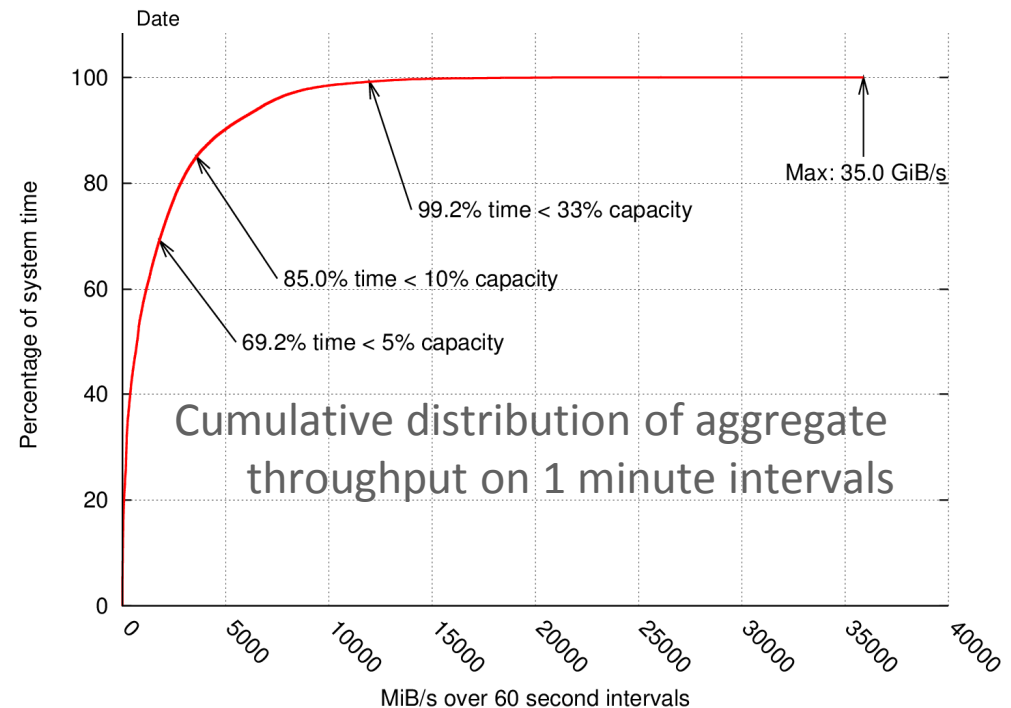
- Darshan includes tools that help users and catalysts investigate the behavior of individual jobs in greater detail
- This example project accessed 3.5 PiB of data over 2 months
- Low performance, despite some positive characteristics like relatively large access size
- File usage:
 - Over **1 million files** accessed by some 4096 process script jobs
 - One read or write per file
- 95% of I/O time was spent performing metadata operations
- Write-only files holding back performance despite high read ratio
- ... *but interpreting behavior and suggesting improvements is a manual process that requires knowledge of the storage system and I/O tuning experience.*



What about production behavior at the system level?



- Several off the shelf tools exist, and relatively modest instrumentation can yield interesting information
- This data was collected using “iostat”
- Allows us to observe bursty behavior and idle time that could be leveraged by system software algorithms

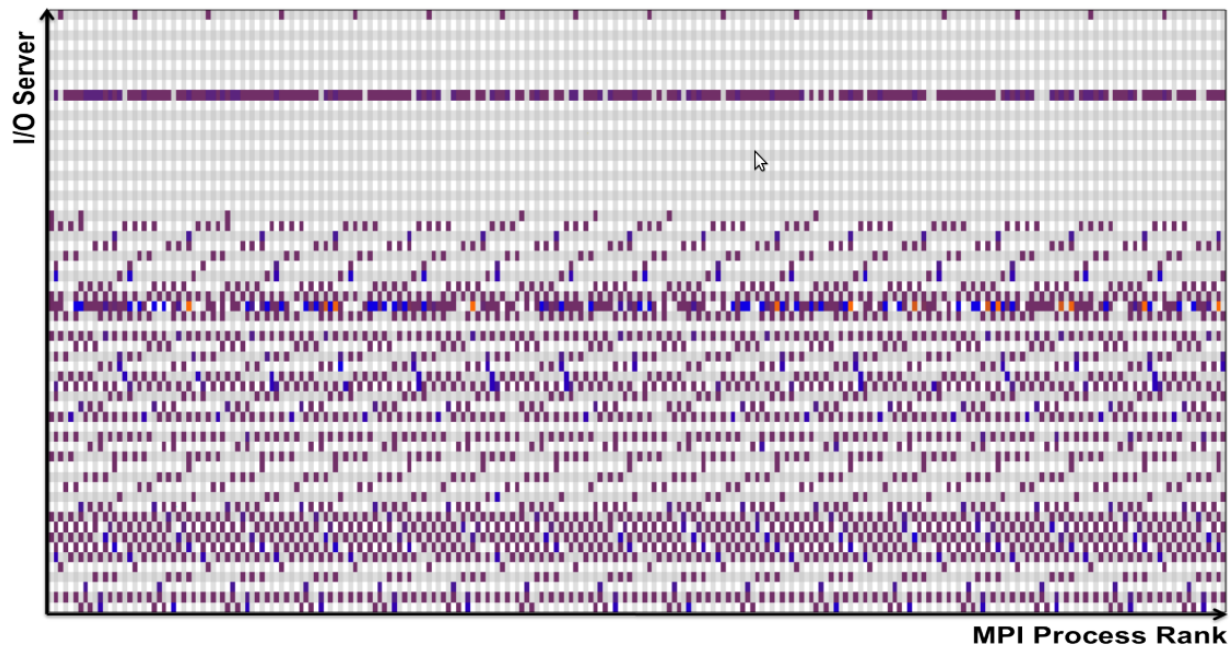


What if we drill down with in-depth instrumentation?

- IOVIS project (UC Davis and ANL)
- Opposite end of the spectrum from Darshan-level instrumentation
- Collects traces that link together:
 - MPI-IO operations
 - File system client operations
 - Network messages
 - File server operations
- Key challenges:
 - **How to capture and store the trace data efficiently**
 - **How to analyze and visualize the results in a meaningful way**
- Scale is a problem both for visualization and data capture
- Traditional time lines and Gantt charts are not clear with thousands of processes
- Requires new methods to interpret results and identify the source of I/O overhead



IOVIS example



- This matrix shows messages intensity between clients and servers using color opacity
- Servers on the Y axis
- Clients on the X axis

- Potential bottlenecks appear as dark horizontal lines
- Poor balance across servers in this example

C. Muelder, C. Sigovan, K.-L. Ma, J. Cope, S. Lang, K. Iskra, P. Beckman, and R. Ross. Visual analysis of I/O system behavior for high-end computing. In Proceedings of the third international workshop on Large-scale System and Application Performance, LSAP '11

Ongoing work on Measurement and understanding


- More deployments and comparisons
 - Hard to draw broad conclusions from a single system
 - Early success at LLNL (Richard Hedges), TACC (Bill Barth), and others
- Investigating trends discovered from early analysis
 - How bad is the I/O variance, and where does it come from?
 - What factors have the greatest impact on performance?
- Production ramifications
 - How can we improve turnaround time in analyzing data?
 - Can we utilize historical job information for I/O-aware scheduling?
- Tuning efforts for a variety of applications (Gpaw, Phasta, HSCD, etc.)

job	Job classification					I/O time by slowest rank (seconds)				
	samples	procs	files	GiB rd	GiB wr	mean	min	max	stddev	CV
EarthScience A	571	2048	57349	624.4	2.8	939.9	185.9	2034.5	186.7	19.9%
EarthScience B	171	4096	57349	927.8	2.8	1157.4	767.9	1564.4	111.0	9.6%
NuclearPhysics A	404	2048	4	4.3	0.0	23.1	19.1	248.8	21.3	92.1%
NuclearPhysics B	407	4096	4	4.3	0.0	24.3	19.1	1291.7	63.7	262.2%
NuclearPhysics C	837	4096	10809	791.1	326.8	450.4	396.4	3764.1	134.3	29.8%
NuclearPhysics D	809	4096	9815	626.8	122.5	246.7	225.4	658.3	29.5	12.0%
Climate A	8	3888	24455	353.8	100.5	720.1	662.1	835.6	56.9	7.9%

Open questions for Measurement and Understanding

- How can we be more proactive with the data we gather?
 - Automatically identify soft system failures, applications in need of assistance, etc.
 - Automatically tune system and library parameters
 - **Towards autonomous storage**
- How do we extrapolate I/O behavior to exascale?
 - A key issue for the CODES simulation project (ANL and RPI)
 - What workloads will be most important? What will the job mix look like?
 - Changes in concurrency and granularity
- How do we manage the data that we are collecting?
 - Fairly compact for individual jobs right now, but broad queries and analysis are not easy
- How much instrumentation can we perform in production?
 - Darshan might have been a little too conservative
 - If we had more data, what would we do with it?





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